Enhanced Condensation for Organic Rankine Cycle

10th Quarterly Progress Report

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1. BACK GROUND

Generating electricity from low grade heat sources has attracted attention due to rising fuel price and increasing energy demand. The organic Rankine cycle (ORC) system is the most practical solution among technologies developed for low grade heat recovery. However, the efficiency of a typical small scale ORC is 10% or less. Most energy loss in the ORC is attributed to thermodynamically irreversible heat transfer processes occurring in its heat exchangers: the evaporator and condenser. In particular for waste heat recovery ORCs, economical success is mainly determined by effectiveness of the condenser because, while their heat source is provided at no cost, heat rejection accounts for most of operation cost. Almost half of total cost for operation and maintenance of an ORC system can stem from its condenser. We investigate and demonstrate heterogeneous condensing surfaces that potentially reduce the irreversibility during the condensation of organic fluids.

2. PROGRESS REPORT

During the reporting period (April 1 – June 30, 2015) the testing apparatus was unexpectedly damaged, so we investigated the cause of the damage. After identifying the cause, we repaired and modified the apparatus to prevent a similar incident.

Damage to the apparatus

The condensation testing apparatus was moved to a fume hood in Lab 230 Duckering Building at the University of Alaska Fairbanks since we would deal with a high pressure organic fluid such as R-134a. After a series of leaking test using air the apparatus was confirmed to show no leaks. On April 17, 2015 the apparatus was charged with R-134a for the first time. The system pressure was maintained at approximately 87 psia. The evaporation chamber exploded in the fume hood approximately 90 minutes after charging. Figure 1 shows a photo of the apparatus charged with R-134a before it exploded.

Figure 1: The testing apparatus is charged with R-134a. The pressure is measured about 87 psia.

Figure 2 presents a photo taken after the explosion. The transparent material of the evaporation chamber broke into pieces. The fume hood sucked the vaporized R-134a.

Figure 2: The evaporation chamber explored after approximately 90 minutes after charging R-134a.

The cause of the damage was identified. Material of the cylindrical chamber was acrylic, and it is reactive with some organic refrigerants including R-134a [1]. Exposure of the acrylic chamber to R-134a made it brittle, lowering its maximum allowable stress. This led to explosion even though the system pressure was maintained at a constant value.

The cylindrical wall was replaced with polycarbonate having the same wall thickness. Polycarbonate is known to be chemically safe with R-134a [1] and possesses a higher maximum allowable stress than acrylic. A photo of the current apparatus with replacement is seen in Figure 3. The current system passed a series of leak tests using 170 psia compressed air. It is now ready for experiments of R-134a condensation.

Figure 3: The current testing apparatus in a fume hood.

Reference

[1] DuPont refrigerants HFC-134a Properties, Uses, Storage, and Handling, http://people.rit.edu/megite/440r134a.pdf.

Appendix

COMPATIBILITY OF REFRIGERANTS WITH PLASTICS, ELASTOMERS AND METALS

Compatibility with plastics. Information on compatibility of refrigerants SUVA® R11, R12, R22 and R502 with plastics is given in table down, however, for each separate case of using it is necessary to perform compatibility tests because plastics of the same type have different molecular mass, structure of polymers, different plasticizers, and temperature and other factors can decrease plastics resistance to the influence of refrigerants.

Compatibility of SUVA®

Plastics and elastomers (trade mark)	R11	R123	R12	R134a	R401A R401B R401C	R22	R407C	R410A	R502	R402A R402B	R404A	R124
ALATHON	1	1	1	0	1	1	0	0	1	-	0	0
Polypropylene	2	1	1	0	1	1	1	1	1	1	0	1
Polysterene (Sryrol)	2	2	1	1	2	2	1	1	2	2	1	1
Chlorinated PVH	1	1	0	0	1	1	0	0	1	1	0	0
PTFE (Teflon®)	1	1	1	1	1	1	1	1	1	1	1	1
ETFE (Tefzel)	1	-	1	1	2	1	1	1	1	1	1	2
PVDF	0	-	0	1	1	1	1	1	1	1	0	0
Ionomer resin (Surlyn®)	2	-	1	0	1	1	0	0	1	1	0	1
Intense resin (Lucite®) (acrillyc)	0	2	0	2	2	2	2	2	2	2	2	2
ABS (Kralfstic®)	0	2	0	0	2	2	-	2	2	2	0	2
Cellulose material (Ethocel®)	2	2	2	2	2	2	2	2	2	2	2	2
Epoxy resins	0	0	0	0	0	0	0	0	0	0	0	0
Polyacytamine (Delrin®)	0	1	0	0	1	1	1	1	1	0	0	0
Polycarbonate (Tuffak®)	0	2	0	0	2	2	-	1	2	2	0	0
Polybutyleneterephtalate (Crastin®)	0	0	0	0	1	0	0	0	0	0	0	-
Polyarylate (Arylon®)	0	-	0	0	2	2	1	1	2	2	0	-
Polyamide (Zytel®)	0	0	0	0	0	0	0	0	0	0	0	0
Polyamide (Vespel®)	-	-	0	-	0	-	0	0	0	0	0	0
PEB (Ultem®)	0	-	0	0	1	1	-	-	1	-	0	0
Polysulfide	0	-	0	0	2	2	1	1	1	2	0	0

Designations: 0 - good compatibility, 1 - compatibility on the verge of permissible; 2 - non-compatibility

Compatibility with elastomers. As the laboratory research by "Du Pont" company has showed (see table up), elastomers, which successfully operated in combination with R12, have, as a rule, good compatibility with average pressure service blends (R401A, R401B and R401C) as well - see the table.

However, the degree of refrigerants effect on elastomers can change within a wide enough range depending on what plasticizers, fillers and other ingredients have been used in the compounding of the rubber compound; therefore, for each separate case it is necessary to have tests. Special attention should be paid to checking of compatibility of materials of circular section O-ring seals with refrigerants. Checking is usually performed in the laboratory conditions by sinking of elastomer samples into the liquid refrigerant at the room temperature and keeping it there till maximum swelling. Items with high degree of swelling are not recommended to use in the refrigeration systems charged with SUVA® refrigerants.

Compatibility with metals. The majority of structural metals being used such as steel, cast iron, bronze, copper, tin, lead and aluminum, operate well with SUVA® refrigerants under normal operation conditions, as the research made by "Du Pont" company has showed.

Under very high temperatures (for example, at blanching) some metals can act as catalytic agents accelerating fluorine contextures decay. Alloys of magnesium and aluminum containing more than 2 % of magnesium should not be used in the systems charged with SUVA® refrigerants, especially if moisture can appear.

The majority of refrigerants of HCFC and HFC can react violently with highly active metals, for example, with alkali and alkali-land metals (natrium, potassium, barium, etc.), being in a free state. Metals become even more active in a fine-grained and powder kind. Aluminum and magnesium at that can react with fluorine-containing contextures, especially under high pressure. Such highly active materials cannot be placed in contacting with the refrigerants of HCFC and HFC groups before their reaction has been thoroughly investigated and taken proper safety measures.